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DESIGN CONCEPTS OF DFIG BASED WIND TURBINE CONTROL SYSTEM USING NEURO FUZZY CONTROLLER FOR INDUSTRIAL APPLICATIONS

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ABSTRACT

Extracting energy from the wind by wind turbine plays important role in the renewable energy systems. In the modern world, 'making smart city' is the key concept to generate alternative power. Industries, Institutions, Household appliances, etc. need continuous electrical power for their needs. It can be fulfilled by renewable energy sources such as wind, solar, etc. Designing of variable wind turbine includes capturing of wind energy, conversion from mechanical rotation into electrical, starting and stopping of turbine system. These are not limited to the above, but also considering aerodynamic blade design, design of complete wind system, design of hub, generator structure and so on. For better performance of wind turbine, a control strategy can be designed so that the performance of the Power electronic components and generator used in wind turbine system can be enhanced. An optimization technique has been stated here along with intelligent control design. In this article, design concepts, performance measurement and storage capacity of wind power systems and Intelligent Controllers have been explained.

KEYWORDS: Variable Wind Turbine, DFIG & Intelligent Controllers

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Original Article

INTRODUCTION

Renewable energy sources such as wind, solar, geothermal, hydroelectric, and biomass provide significant benefits for our the economy of the nation and the environment. It reduces environmental pollution from the gases which are more harmful like Carbon dioxide, methane, nitrous oxide. In 2014, carbon dioxide accounted for just over 80% of the greenhouse gases emitted into the atmosphere. So there are a lot of good reasons to move toward the use of renewable energy both now and in the future. For example, in the coal mining process it produces solid wastes to the earth surface that would normally be in the underground areas and barren for the generations. And also it produces lot of particulate matters which causes for air pollution. The tiny particles of these may be inhaled deeply and cause for various respiratory problems. People who are working in the plant are getting affected a lot. Sometimes it causes for acid rain which destroy the health of the soil and water sources. Other sources of energy are finite and will someday be depleted, but Renewable energy will not ever run out. According to data aggregated by the International Panel on Climate Change, life-cycle global warming emissions associated with renewable energy, including the factors manufacturing, installation, operation and maintenance are comparatively minimized. Compared with non renewable sources of energy production, wind emits only 0.02 to 0.04 pounds of CO2E/kWh. Since heart of any renewable wind power generation system is the Wind Turbine, the design concepts of a rotor, a

DC generator or an AC alternator which is mounted on a tower high above the ground.

NECESSSITY OF WIND TURBINE DESIGN

It is important to analyze wind turbine design. It is the opposite to a conventional desktop fan. The kinetic energy is captured by the rotating wind turbine blades and converts it into electrical energy. The wind speed and the area that is swept by the rotating turbine blades determine the available power. The fastest wind speed and largest rotor blades produce more electricity. So the design of wind turbine system depends on the interaction between the wind and rotor blade.

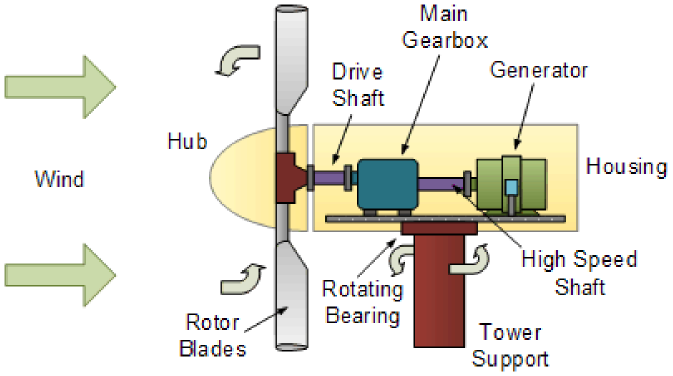

Figure 1: Internal Structure of Wind Turbine

DESIGN CONSIDERATION

The design of wind turbine includes improvement in the parameters such as theoretical efficiency, propulsion, practical efficiency, blade design, and blade loads, etc. The wind turbine design is classified into horizontal axis wind turbine and Vertical axis wind turbine [1]. The rotor design in both the configurations is different. The power output is higher than that of a vertical axis design because HAWT turbine catches more wind than others. The only disadvantage of horizontal design is that it requires tallest tower and much better rotor blades. On the other hand, it is easier to design and maintain the vertical axis wind turbine. While comparing with HAWT, it has low performance.

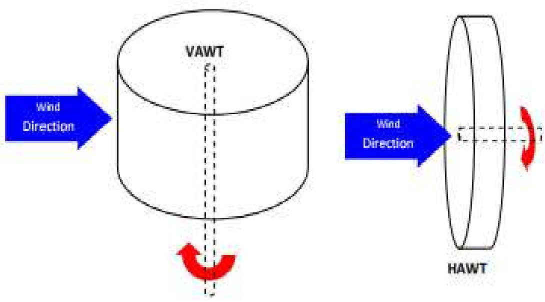

Figure 2: Configurations of Shaft rotor

DFIG in Wind Turbine

Power electronics converters, interface with doubly fed induction generator which is very much used in wind turbine system to control rotor current and to achieve the variable speed that captures maximum wind. Collecting of wind energy and transforming into mechanical power is done by the rotor of the turbine. Power losses and cost are comparatively low in a DFIG based wind turbine. The physical system includes wind turbine blades, shaft for supporting for rotation, back-to- back power electronic converters, transformers, and transmission line and grid connections. This

conventional method can be replaced by battery system arrangement where power will be stored instead of sending to the grid. The storage capacity of the system can be improved further. The conventional grid connected wind turbine system is shown in the figure below.

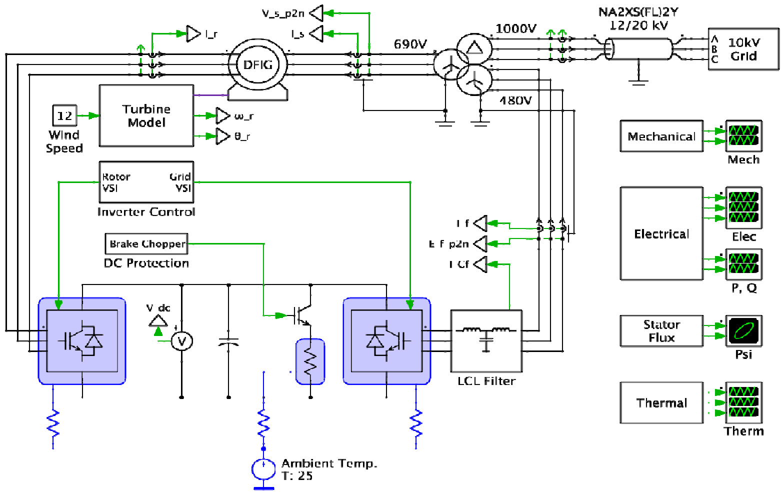

Figure 3: Model of DFIG Based Wind Turbine System- Power Circuit

In this power circuit the rotor of DFIG is directly connected to the grid via transformer. Rotor of the system is connected to power electronic converters via slip rings. The transformer tertiary wind is connected with grid side of the converter. The recent development is to avoid the drawbacks of direct inline converter based adjustable speed drives [2]. It consists of a DFIG with four quadrant AC- AC converters on insulated gate bipolar transistor connected to the rotor windings.

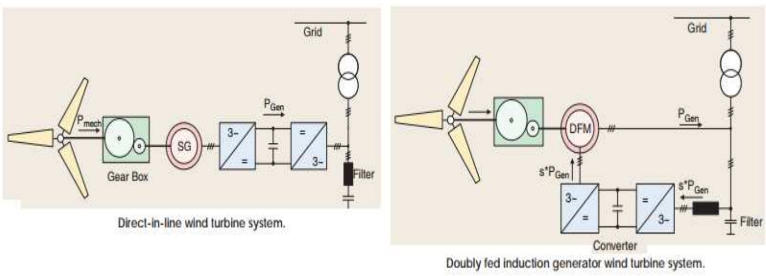

Figure 4: Comparison of Direct Inline and DFIG

CONTROLLER DESIGN

The active power controller can be designed with a proportional - integral controller with simple arrangements and design concepts. The high dynamic performance is achieved by the terms sensitivity and reference tracking [3].

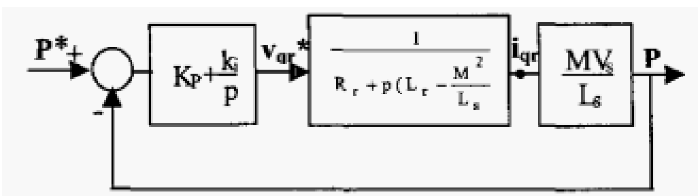

Figure 4: Active Flow Control

The non-linear function can be classified or approximated by adaptive Neuro Fuzzy Inference System. Online

identification is done very effectively. Back propagation based algorithm is used to collect the input and data. It is an integrated model in which artificial neural network is used to develop a fuzzy system in order to make the wind turbine system more reliable. The extraction from wind turbines will be optimum.

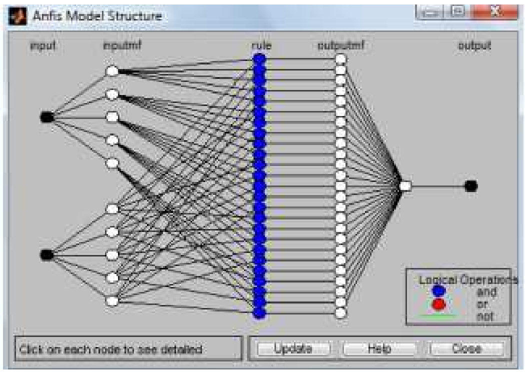

Figure 5: Model of ANFIS

The modeling includes the layers of the system, two inputs, O/P, Velocity, Reynolds number. Normally, the neural network is functionally equivalent to fuzzy inference system the fuzzy variables considered here are very low (VL), low (L), medium (M), high (H), and very high (VH). To develop the fuzzy inference system and train ANFIS MATLAB can be used. The maximum prediction accuracy will be more in this system [6].

When wind velocity and the Reynolds number reached maximum, the generation of wind power will be maximum and vice versa. Since wind cord length is fixed as constant and based on the variation of lower level air density the Reynolds number can be calculated. At instant to instant or place to place, the prediction of wind power generation is continuously varying one. So it should be noted that to keep the wind power generation within the specific limit. However, the fuzzy sets are quit complex and the improvement will be small so it increases the computation time of the system.

RE \ WV	VL	L	M	H	VH
VL	VL	VL	VL	VL	L
L	VL	L	M	M	H
M	M	M	M	M	H
H	M	M	H	H	H
VH	M	H	H	VH	VH

Ffigure.6. Rules for ANFIS

OPTIMIZATION TECHNIQUES

Improvising the performance of the wind turbine system includes the maximizing power yield, operational performance, DFIG stator and rotor, and etc. Optimizations of design concepts need multiple parameter model evaluations. When number of parameters which are to be modeled increase, by default the number of evaluations required also increases. So it is important to reduce the number of iterations so that mathematical calculations will be reduced. So by considering the above said, an optimization method must be proposed. To optimize the limited available information for wind profile and generator operating conditions, particle swarm optimization-based surrogate optimization technique is used along with finite element analysis. This method is compared with direct optimization technique.

To converge on optimum in design space, direct optimization can be employed after the intermediate process.

The work flow of the direct optimization technique is shown in the figure below.

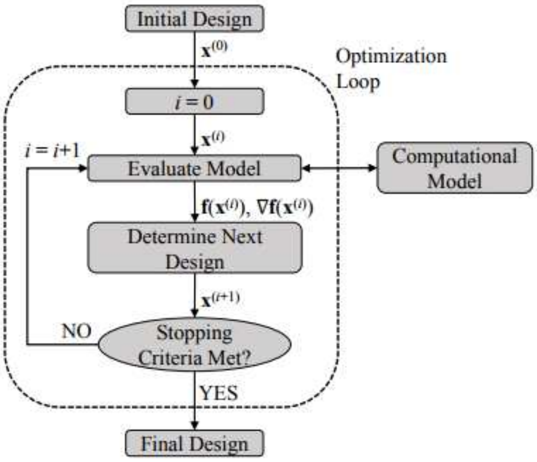

Figure 7: Work Flow of Direct Optimization

Surrogate-Based Optimization

SBO are the methods, which utilize a surrogate model of the objective function. In general, it is used in an intermediate step between evaluation of the objective function and selection of the next design to sample. This is shown in the figure below.

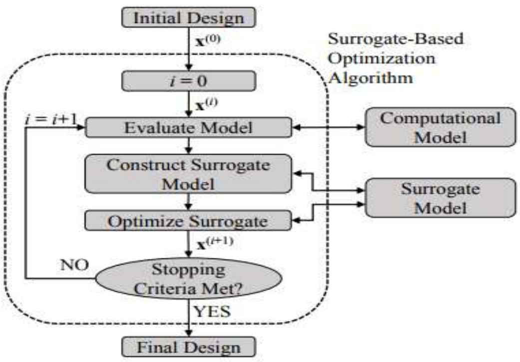

Figure.8: Work Flow of SBO Algorithm

The following environmental and other conditions such as Climate change, resource depletion, and worldwide urbanization feed the demand for more energy and resource-efficient buildings this technique is highly employed. Increasingly, architectural designers and consultants analyze building designs with easy-to-use simulation tools.

CONCLUSIONS

In general, the basic design methodologies of wind turbine design have been discussed. As far as industry scenario is concerned, the latest innovation is Industrial Internet era. The Digital Wind Farm makes wind turbines smarter and more connected. The digital infrastructure allows the customers to connect forever, monitor, control, predict and optimize the wind site performance. And also it makes more adaptable wind energy ecosystem. Comparatively, Vertical axis turbines are not completely disregarded for future development. To make it most suited a novel V-shaped rotor design can be investigated, which can satisfy the basic requirements. In addition to these basic concepts, a complete design perspective

based wind turbine will be modeled and analyzed.

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